Unit 12: Using Statistics in Science

Unit code: F/502/5547

QCF Level 3: BTEC National

Credit value: 5

Guided learning hours: 30

Aim and purpose

This unit enables the learner to use statistical techniques that are essential for the handling, collection and interpretation of scientific data.

Unit introduction

This maths unit enables the learner to build on knowledge gained from *Unit 11: Using Mathematical Tools in Science* or GCSE mathematics to investigate further mathematical tools used in all disciplines in science. Learners will answer questions such as:

- What do I do with the data collected in the laboratory?
- How reliable is the data collected?
- What does the data mean?
- Is there a relationship between the data collected?

The first section introduces basic probability theory and standard deviation and the various types of data that can be collected. Learners will consider how to use a scientific calculator to manipulate statistical data. The next section introduces various statistical tests that are used in science, such as the chi-squared test and how it can be used to support a scientific hypothesis, for example in ecology and genetics.

The t-test is introduced next, with examples of how this test can be applied to scientific data that learners will collect in the laboratory. The section ends with looking at various correlation methods that are used in investigating relationships between various scientific quantities.

Throughout this unit, there are lots of opportunities for integrating computational methods; from calculator work to spreadsheets. In summary, this unit is an important introduction to statistics in the context of science. It is invaluable to learners who are working with scientific data at Level 3 and beyond.

Learning outcomes

On completion of this unit a learner should:

1 Be able to use statistical techniques to investigate scientific problems

2 Be able to perform statistical tests to investigate scientific problems.

Unit content

1 Be able to use statistical techniques to investigate scientific problems

Probability: addition and multiplication rules; conditional probability, eg lottery, sampling, population

Frequency distributions: discrete data; continuous data (grouped and ungrouped)

Shape of distributions: unimodal distributions (normal distributions and skewed distributions); bimodal distributions (qualitative explanation)

Statistical data calculations: calculation of the mean, $\bar{x}$ ($\bar{x} = \frac{\sum x}{n}$); mode; median; calculations of standard deviation, s ($s = \sqrt{\frac{\sum\left(x - \bar{x}\right)^2}{n-1}}$); using ICT equipment to calculate the standard deviation; entering statistical data into ICT equipment; retrieving statistical information from ICT equipment; standard error of the mean; confidence limits

Normal distribution: mean; variance; use of tables of the cumulative distribution function; application of the normal distribution in science

Sampling: random sampling (quadrant in field sampling); population and sample (Gallup or Mori poll); standard error of the mean (the uncertainty in the average value of a set of measurements), eg the chlorine content of river water

2 Be able to perform statistical tests to investigate scientific problems

Chi-squared test: ($\chi^2 = \sum \frac{(O-E)^2}{E}$), where O is the observed frequency and E is the expected frequency; degrees of freedom; contingency tables; science-related applications of the chi-squared test, eg populations in different habitats, size of cockles on different shores, genetics, toxicity, any other science-related test

The t-test: independent samples; related samples (matched pairs); applications, eg equal number of seeds in two different composts, leaf size of nettles in shaded/unshaded areas, test whether a particular fertiliser improves yield of tomatoes, any other science-related test

Correlation testing: graphical test, eg line of best fit; linear regression, eg using a calculator in linear regression mode; testing for power law, eg radioactivity experiments, electrical experiments, any other science-related example

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 carry out statistical calculations to investigate a scientific problem [IE1]	**M1** perform a calculation using probability to investigate a scientific problem	**D1** interpret shapes of distributions in scientific data
P2 perform a chi-squared test to support a scientific hypothesis [IE1; RL3, 5]	**M2** interpret the results of the chi-squared test	**D2** evaluate the validity of the interpretation of the results of the chi-squared test
P3 perform a t-test on data collected from a laboratory experiment [IE1; CT2, 6]	**M3** interpret the results of the t-test	**D3** evaluate the validity of the interpretation of the results of the t-test
P4 carry out an appropriate correlation method to investigate data collected from a laboratory experiment. [IE1; RL3, 5; CT2, 6]	**M4** interpret the results of the correlation.	**D4** evaluate the validity of the interpretation of the results of the correlation.

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key			
	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

As in *Unit 11: Using Mathematical Tools in Science*, and *Unit 13: Mathematical Calculations for Science* this unit should be delivered in a vocational setting and in conjunction with experimental activities. Since scientific calculators are used extensively in performing statistical calculations it is expected that learners will gain experience in the full range of statistical functions available to them. For learning outcome 1, basic probability theory should be delivered in the context of scientific and real-life situations, for example in ecology, genetics, reaction rates in chemistry and radioactive decay in physics. Learners should have at least a qualitative understanding of shapes of distribution so that they can compare between the normal and other skewed distributions. The normal distribution should be taught with the use of tables of the cumulative distribution function and linked to normal distributions found in science.

Learning outcome 2 offers the opportunity for learners to test laboratory work using a number of statistical tests. This section will come alive by comparing various statistical tests to primary and secondary data collected by learners. For example, for the chi-squared tests, learners could look at data for populations of animal or plant species in different environments or genetic models. For correlation testing, learners will have many opportunities to use data collected during experimental work and to use various computer software available. When offering assessment opportunities it is vital that learners can develop an understanding of a set of data, from the collection stage (normally a pass criterion) to an interpretation of the test (the merit criterion) and then finally an evaluation stage (the distinction criterion). It is a common mistake for learners to describe general limitations and comparisons of the tests without relating these discussions to their collected data.

The examples indicated in the *Unit content* give the tutor ideas of what could be discussed and are not limited to those mentioned. However, it is expected that at least one of the examples will be covered during lessons.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction and outline scheme of work
Learning outcome 1 – Statistical techniques
Probability
Learning activity: card matching activity on the rules.
Learning activity: using probability in science – group discussion.
Frequency distribution and shapes
Learning activity: shapes matching activity.
Calculations (mean, standard deviation).
Learning activity: worksheet problem solving.
Use of calculator in statistics
Learning activity: worksheet: using calculator to solve stats problems – compare with manual method.
Assignment 1: Statistical Calculations (P1, M1, D1)
Learning outcome 2 – Statistical tests
Chi-squared test
Learning activity: worked example of using chi-squared test (paired activity).
Learning activity: problem-solving activity on chi-squared test.
The t-test
Learning activity: using t-test in science (group discussion).
Learning activity: worksheet – problem solving using t-test
Correlation testing
Learning activity: linear regression as used in science.
Learning activity: testing power laws.
Learning activity: perform experiment to test relationship.
Assignment 2: Chi-squared Test (P2, M2, D2)
Assignment 3: T-test (P3, M3, D3)
Assignment 4: Correlation Testing (P4, M4, D4)
Review and evaluation of unit and assessment.

Assessment

To achieve P1, learners must correctly calculate standard deviation, retrieving statistical information from a calculator and calculate standard error and confidence limits. Learners must also demonstrate that they can solve calculations involving probability. For M1, learners must solve at least two scientific problems using probability. D1 can be obtained by learners identifying scientific data that has been collected from an experiment and describing its distribution, including calculating its standard deviation. The scientific data must include data from physics, chemistry and biology, although one set of data needs to be from an experiment. The other two could be secondary data.

For P2, learners must perform a chi-squared test on any scientific hypothesis. M2 can be obtained by interpreting the results of the chi-squared test done for P2. For example, by explaining what the results actually mean to the original investigation. For D2, learners need to evaluate their results by considering how reliable their data was and any limitations of the test. The evaluation must be related to P2 and M2.

For P3, learners need to perform a t-test from data collected from an experiment. One scientific discipline is enough for P3. Criterion M3 can be obtained by interpreting the results of the t-test done for P3, again by explaining what the results actually mean to the original investigation. For D3, learners need to evaluate their results by considering how reliable their data was and any limitations of the test. The evaluation must be related to P3 and M3.

For P4, learners must successfully carry out an appropriate correlation method to investigate data that they have collected from a laboratory experiment. The experiment should be different from the one used for P2 and P3. If computational methods are used, learners should give details of the correlation method. M4 can be obtained by interpreting the results of the test used in P4. Learners will again need to explain what the results mean to the original investigation. For D4, learners need to evaluate their results by considering how reliable their data was and any limitations of the correlation method used. The evaluation must be related to P4 and M4.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, M1, D1	Statistical Calculations	Trainee scientist working in a science organisation.	Problem solving. Experimental data.
P2, M2, D2	Chi-squared Test	Trainee scientist working in a science organisation: department A.	Experimental data collection analysis.
P3, M3, D3	T-test	Trainee scientist working in a science organisation: department B.	Experimental data collection analysis.
P4, M4, D4	Correlation Testing	Trainee scientist working in a science organisation: department C.	Experimental data collection analysis.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC in Applied Science sector suite. This unit has particular links with the following units in the BTEC Applied Science suite and the BTEC Environmental Sustainability suite:

Level 2	Level 3
Using Mathematical Tools in Science	Mathematical Calculations for Science
	Undertake an Extended Investigative Project in the Environmental Sustainability Sector
	Undertake an Investigative Project in the Environmental Sustainability Sector

Essential resources

This unit aims to develop learners' skills in mathematics and statistics in the context of practical science. It is, therefore, important that learners have access to facilities to carry out practical scientific work for demonstration and practice. There are several mathematics packages that would be useful for teaching purposes. It is important that learners have access to scientific calculators and computer software, such as spreadsheet applications, as well as to the internet. This unit has mathematical content at Level 3 standard and suitably experienced staff are needed to deliver it.

Employer engagement and vocational contexts

Links to scientific organisations, their technicians and scientists would extend the vocational relevance for learners and provide a valuable experience and resource.

Indicative reading for learners

Textbooks

Foale S, Hocking S, Llewellyn R, Musa I, Patrick E, Rhodes P and Sorensen J – *BTEC Level 3 in Applied Science Student Book* (Pearson, 2010) ISBN 9781846906800

Attwood G, Dyer G and Skipworth G – *Revise for Statistics: No 1 (Heinemann Modular Mathematics for Edexcel AS & A Level Statistics)* (Heinemann Educational Secondary Division, 2001) ISBN 9780435511166

Attwood G, Dyer G and Skipworth G – *Revise for Statistics: No 2 (Heinemann Modular Mathematics for Edexcel AS & A Level Statistics)* (Heinemann Educational Secondary Division, 2001) ISBN 9780435511173

Cook P and Wheater C – *Statistics for Environmental Investigations* (Taylor and Francis Ltd, 2000) ISBN 9780415198882

School Mathematics Project – *Statistics 1 for Edexcel (SMP AS/A2 Mathematics for Edexcel)* (Cambridge University Press, 2004) ISBN 9780521605359

School Mathematics Project – *Statistics 2 for Edexcel (SMP AS/A2 Mathematics for Edexcel)* (Cambridge University Press, 2005) ISBN 9780521605397

Townend J – *Practical Statistics for Environmental and Biological Scientists* (John Wiley and Sons Ltd, 2002) ISBN 9780471496656

Journals

Environmental and Ecological Statistics

Journal of Applied Statistics

Journal of Environmental Statistics

Statistical Modelling: An International Journal

Teaching Statistics

Websites

Blackwell Statistics	www.blackwellpublishing.com/subjects/PB
Royal Statistical Society	www.rss.org.uk
Teaching Statistics Trust	www.rsscse.org.uk/ts

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	identifying a scientific question which the application of statistics would help to answer, and determining the most appropriate statistical methods to use
Creative thinkers	carrying out a statistical method
Reflective learners	using the chi-squared test to support or negate their findings, and considering what improvements could be made to their plan.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Independent enquirers	solving a scientific problem using probability
Creative thinkers	interpreting various statistical tests
Reflective learners	comparing statistical tests
Self-managers	organising time and resources in order to submit their assignments within deadlines
Effective participators	explaining the findings of their statistical tests to peers.

Functional skills – Level 2

Skill	When learners are ...
Mathematics – Representing	
Understand routine and non-routine problems in familiar and unfamiliar contexts and situations	processing and manipulating their quantitative results using appropriate statistical methods
Identify the situation or problems and identify the mathematical methods needed to solve them	planning and carrying out a statistical method
Mathematics – Analysing	
Apply a range of mathematics to find solutions	applying the appropriate correlation method to the data collected
Use appropriate checking procedures and evaluate their effectiveness at each stage	using the chi-squared test to support or negate findings, and considering what improvements could be made to their plan
Mathematics – Interpreting	
Interpret and communicate solutions to multistage practical problems in familiar and unfamiliar contexts and situations	solving probability problems in science
Draw conclusions and provide mathematical justifications	carrying out statistical tests and then deciding if a hypothesis is valid or not.